THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. I.

Tallong–Bungonia.

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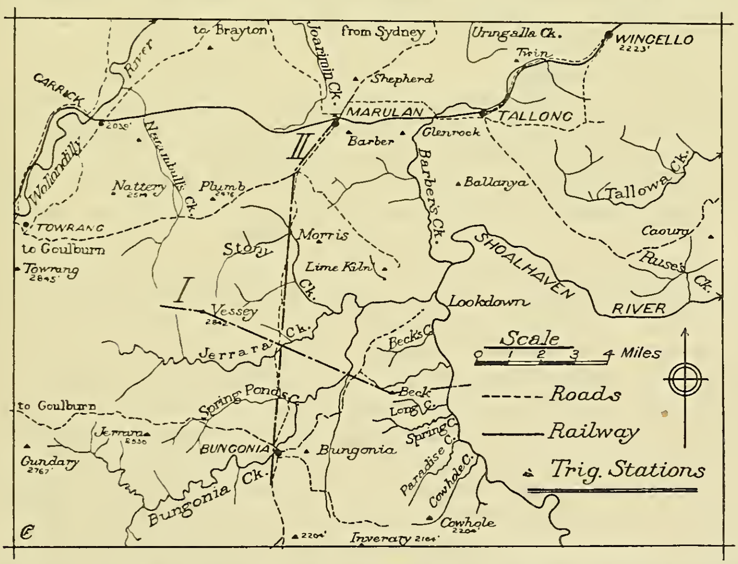
(Plates iv–vii; ten Text-figures.)

[Read 29th April, 1931.]

This is the first of a series of papers in which it is proposed to deal with the physiography of the Shoalhaven Valley, from the head of the river to a point some ten miles south-east of Tallong. This area of 2,600 square miles includes much broken and mountainous country which is difficult to traverse, and considerable stretches of level plains. Areas such as that dealt with in the present paper, which are capable of yielding the most valuable information, are to be studied in detail, whilst others will be investigated by more general methods. The actual methods employed depend largely upon the nature of the country involved. Obviously any considerable physiographic survey in mountainous country is not practicable, and the absence of any feature survey over considerable areas of such country is a disadvantage.

The writer wishes to thank the Surveyor-General and Mr. L. H. Bowler of the Lands Department for making maps and survey information available. In field-work, the help and hospitality of Mr. and Mrs. J. G. Hoare and family of Tallong



Text-fig. 1.—Locality Map of the Area. The Main Southern Highway passes through Marulan and Towrang.

have been invaluable. Parts of the work incorporated in this paper have been discussed with Professors Cotton, Browne and Macdonald Holmes, to the latter of whom the inclusion of Text-figure 5 is due.

Unless otherwise stated, all heights quoted are referred to sea-level, and the magnetic meridian is used throughout (declination = 9° 35′ E.).

The Area Dealt With. (Text-figs. 3, 7.)

Between Moss Vale and Goulburn, on the Main Southern Railway of New South Wales, there is an expanse of upland plains, with low ridges and tableland masses rising above the general level. In places the railway passes through fertile basalt country, but the general impression is one of sandy uplands and gentle stream valleys, the latter seeming to wind blindly into low hills. To the south are steep-sided gorges and ravines which have been carved by the Shoalhaven River in the course of its attack upon the highlands. These cannot be seen from the railway, and their presence is only appreciated when, in crossing an apparently unbroken plain, a traveller finds himself on the edge of a precipice with a stream many hundreds of feet below.

In this part the Shoalhaven, previously following a northerly course, turns sharply eastward to enter the sea below Nowra. The outer side of the great elbow bend thus formed consists of the uplands observed from the railway, which continue southward to form extensive plains to the west of the river. The higher points exist because of the resistance which their component material offers to weathering and erosion and, their slopes having been exposed to the weather over great periods of time, their sides are littered with rock debris.

The sides of the modern canyons are still very steep, and they either carry a thin covering of scree or consist of lightly-forested rock slopes. Such complex gorges as those found in the more dissected parts of the Blue Mountain Tableland are absent for, although the stream pattern is intricate, the tributaries have not cut back very far from the main gorge, which has a simple enough appearance when viewed from the uplands.

The country on the concave side of the great elbow presents a very even skyline before the commencement of the eastward coastal fall, but its surface covering of almost horizontal sandstone has favoured the development of precipices along all of the steeper stream courses, making that part very difficult of access. The river has cut it off completely from the railway side, and thus forms an excellent natural boundary for purposes of survey, classification or description.

Previous Literature.—The chief published accounts of this area are those of Andrews (1904), Woolnough and Taylor (1906) and Woolnough (1909). In the second the authors postulate a previous connection between the Upper Shoalhaven and Wollondilly Rivers. This stream line, they state, was finally broken after the period of uplift which formed the modern plateau and allowed the present lower Shoalhaven to cut back and capture the stream which now forms its headwaters. Evidence for the existence of the stream line referred to depends on certain mature valleys, stream gravels and a breached divide on the uplands, the three being intimately associated. Taylor has also referred to Kangaroo River—a more easterly tributary of the lower Shoalhaven—as having flowed originally westward past Tallong to the postulated main stream. Andrews, the pioneer of Australian physiography, regarded the lower Shoalhaven as an eastward-flowing stream of considerable antiquity—a conclusion which would appear to be amply supported by the field evidence adduced here.

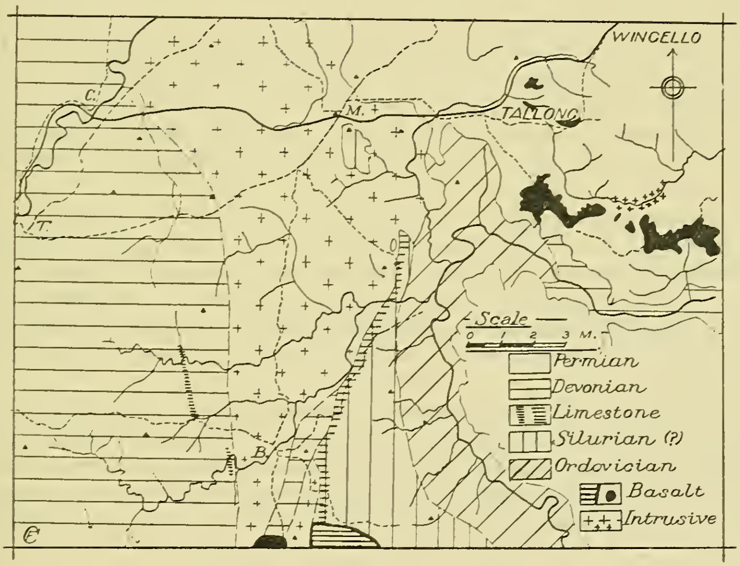
The paper by Woolnough on the Geology of Tallong has been largely availed of, and Dr. Woolnough's map is incorporated in Text-fig. 2. On the geological side reference may be made to recent accounts of Tertiary contact quartzites by Ida Brown (1926) and Waterhouse and Browne (1929).

As regards physiography, detailed work has not been done over any part of the Shoalhaven Valley and, although Woolnough and Taylor's capture hypothesis has been criticized, no alternative explanation has been published.

Geology and Resistance to Erosion. (Text-fig. 2.)

The physiography of the district has been greatly affected by the character and structure of the rocks. Systems ranging in age from Tertiary to Ordovician are represented, in addition to intrusive and volcanic igneous rocks. These may be classified for present purposes as follows:

Tertiary.—Quartzites are found near flows of Tertiary basalt and in places from which basalt has presumably been eroded. This material has been referred to as silicified Tertiary sands by Brown (1925), and has been described by



Text-fig. 2.—Geological Sketch Map of the Area. Other details are shown on Plates v and vi, and Text-fig. 8. Triassic strata occur in the extreme north-east.

Waterhouse and Browne (1929). The quartzite is generally white or light-grey in colour, is brittle, and generally breaks with a conchoidal fracture. It contains crystals of quartz up to a half-inch across, and is easily distinguished from the fine-grained and much more resistant older quartzites. It resists weathering much more than the overlying basalt, and is frequently found quite away from any surviving flows (Text-fig. 8). Notable occurrences of this latter type are to the west of Ballanya Trig. Station (2,000 feet); to the south of Jerrara Creek (1,950 feet); on a hill near Bungonia Trig. Station (2,000 feet); and to the south of Bungonia Creek (1,870 to 1,970 feet). It will be seen that these occurrences correspond over a limited range, and compare with the base of the Caoura flow (between Tallowa Creek and the Shoalhaven River), which is below 1,850 feet on its eastern extremity.

This quartzitic material is readily distinguished from older sandstones which have been invaded by intrusive rocks. Examples of these latter are found at Bungonia Trig. Station and on the Goulburn road, a mile and a half west of Bungonia at 2,020 feet. In these cases the sandstone is altered to quartzite in places and has been strongly jointed by pressure, thus breaking into irregular fragments. It contrasts with the porcelain-like Tertiary contact quartzite.

The recognition of this Tertiary material is physiographically important, as it indicates surfaces which existed immediately before the period of basalt flows.

Permian.—Triassic strata hardly occur in this area, although they are extensively developed to the north-east, the edge of the series probably being near Wingello. The Permian Upper Coal Measures and Upper Marine Series are extensively developed, but it is not easy to distinguish between the two, nor is it necessary from a physiographic point of view. At the base of the system near its western edge there are massive beds of conglomerate up to 400 feet thick (Woolnough), which dip gently northward and eastward, and give place to finer sediments. They form a resistant bank on the northern side of Barber's Creek at Tallong, where they consist largely of subangular and rounded quartz pebbles up to 8 inches in diameter. They are shore-line deposits flanking older masses such as Ballanya Hill. A horizon of conglomerate, sandstone and grit in contact with old Palaeozoic rocks marks the base of the Upper Marine Series, and forms a level tableland on either side of the lower Shoalhaven (*i.e.*, below Barber's Creek).

Above this horizon are shales, shaly sandstones and soft sandstones, some of them fine-grained sediments containing masses of quartzite and quartz-porphyry up to 2 feet in diameter, as at the head of Tallowa Creek. In this particular locality the softer rocks have surface impregnations of iron oxide and a limited covering of bauxite, both having been derived from Tertiary basalts and both helping to preserve a level surface to the tableland to the north of Tallowa Creek (Text-fig. 6).

The pebbles of the conglomerates are mainly siliceous metamorphic types with a considerable amount of white reef-quartz. To the north of Barber's Creek the conglomerate bank gives place to shales and sandstones with occasional pebble beds, the change being accompanied by more mature land forms at the head of Uringalla Creek. The master joints of these rocks are approximately north-south and east-west in direction, thus determining the major cliff lines above the modern gorges.

Older Palaeozoic.—Woolnough has described Silurian and Ordovician rocks in the neighbourhood of Marulan. The latter comprise highly-folded shales, slates, cherts and quartzites striking about N. 10° W., whilst the former include slates and limestones whose strike varies from north to N. 35° E. Their dip is about 45° west, and they are overlain on the western side by Devonian slates, shales and quartzites with a similar dip. This conformity has been noticed further south at Windellama, and it is possible that both series are of Devonian age. These rocks have been intruded by granites, and their strike curves in sympathy with the boundaries of the intrusion.

From the physiographic point of view the Devonian series is the most interesting, as the older strata have been reduced to form plains of low relief in the uplands, whilst the Devonian country is marked by the presence of high ridges. The older rocks are broken into small sections by intense jointing and this, added to their natural thin bedding, makes even the hardest of them quite susceptible to mechanical erosion. The Devonian strata, on the other hand, contain beds of massive quartzites separated by weaker slates, shales and limestones. Their edges have been exposed by folding and, as the result of prolonged erosion, the softer rocks have been removed to form a series of strike valleys (Text-fig. 7), whilst the quartzites stand up as parallel isoclinal ridges rising to 800 feet above the valleys.

Igneous.—Reference has already been made to the basalts of the uplands. The Tertiary age ascribed to these depends on the evidence of plant remains found at their base at Wingello, Penrose and the Moss Vale district, and on this ground they are generally referred to as of Pliocene age. Physiographically they can be classed together, as they are found in valleys cut to a common depth of 300 feet in a peneplain surface. They antedate the main uplifts which have produced the present tableland, as those have caused new cycles of erosion to come into existence and to be impressed on the old plain surfaces, of which the basalts form an integral part.

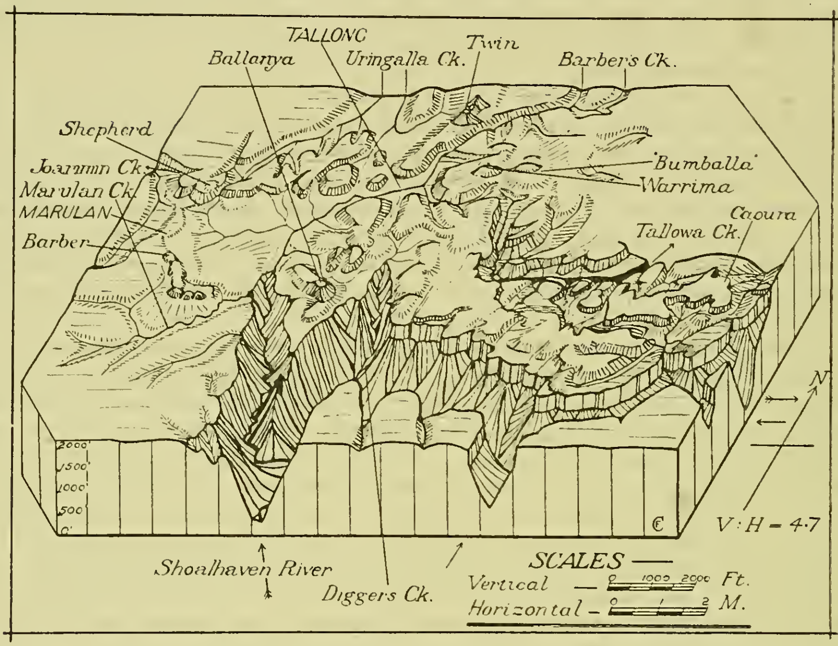
A belt of acid intrusives extends from Tallong southward past Bungonia. It has been described by Woolnough as having a somewhat sill-like form with westerly underlie, although it is not a sill. He points out that, for the Marulan-Tallong area, the mass comprises granodiorite, which passes into dacite and quartz-porphyry towards the west. Acid types continue southward towards Bungonia, with fine-grained felsites on the eastern edge and quartz-porphyry to the west. The general effect of the intrusion has been to give a series of rocks which form undulating surfaces when exposed to weathering over long periods.

From the behaviour of these various rocks when placed in juxtaposition and subjected to uniform attack by weathering and erosion, a fairly accurate idea of their total resistance to these forces may be gained. The outstandingly resistant members are the Devonian quartzites, whilst their associated shales and slates are strongly jointed, fissile and offer comparatively small resistance. Using this topographic basis, of which many illustrations will be found in the succeeding pages, we obtain this scheme, using a descending order of total resistance: (i) Massive Devonian quartzites; (ii) Ordovician quartzites and cherts: various cherts and jaspers; (iii) Tertiary quartzites: porphyries; (iv) Permian conglomerates: Tertiary basalt: acid granite; (v) Granodiorite: Permian sandstones; (vi) Older Palaeozoic slates, shales and limestones: Permian shales.

Topography and Physiography.

i. *Tallong* (Plates v, vi; Text-figs. 3, 6, 9).—Referring to the topographic map it is seen that the vicinity of Tallong is a low maturely-dissected tableland. The double residual which forms Twin Trig. Station at 2,350 feet is capped with hard sandstone, and rises a clear 150 feet above the surrounding country at 2,200 feet. This, in its turn, is 200 feet higher than the plains extending from Tallong toward Marulan.

The area between Barber's Creek and the main road is drained by Uringalla Creek, which flows in a series of broad, mature valleys up to 200 feet deep. The three heads of this stream form a beautiful drainage pattern, although this fact is obscured in the field by dense scrub growing in the flat, alluviated bottoms. The hillsides are covered with sandy soil and pebble drift from the conglomerates which, in this part, are much weakened by the presence of soft shales and sandstones, thus contrasting with the hard bank immediately to the north of Barber's Creek. Of the three heads of Uringalla Creek "A", whose valley is used by the main road, has a gentle grade into alluviated swampy plains up to a half-mile in width. "B" flows through a flat valley and, after heavy rain, it spreads a thin



Text-fig. 3.—Block Diagram of the Tallong District. Note the upper tableland surface, the wide upland valleys and the Caoura basalt flow.

covering of very fine mud over a width of 200 yards; passing the 2,000 feet contour its channel is more definite, although lost in beds of sword grass at intervals. The third head is known locally as "Chain of Ponds", on account of four small ponds occurring in a bend off a quartzite inlier. The ponds are situated in thick, rich black soil at a place where much fine wash has been carried in from tributary valleys. Below this point the stream runs through narrow swamps on to a wide, marshy flat a little below 2,000 feet. Its course here is quite indefinite, but above the ponds a narrowing mature valley is found, through which the stream flows gently.

The local base-level is slightly below 2,000 feet, and erosion has progressed to a point of equilibrium where the force of falling rain-water on the hillsides is insufficient to carry any but the finest material into the streams.

Areas of flat ground with indefinite drainage are found in the continuous valley at the head of Marsh's Creek. This small stream, with a slight advantage in grade over Uringalla "B", is cutting slowly into the swamps. The divide between the Shoalhaven and Wollondilly waters has a minimum elevation here of 2,025 feet, and the conditions are those of mature dissection. The higher plain at 2,200 feet has been dissected to 2,000 feet, whilst the higher Twin residual points to the former existence of a still older and higher land surface.

ii. *Barber's Creek–Eastern Valleys* (Plates v, vi; Text-figs. 3, 6).—The basalt hills of Warrima and Bumballa slope gently northward and give place to wide valleys between 2,100 and 2,200 feet. These slopes act as the gathering grounds of Barber's Creek, which is also greatly assisted by level swamps on sandstone country to the north-east. The hills around the eastern and southern edges of the basalt rise to 2,250 feet, and are marked by deposits of pisolitic bauxite containing a good deal of iron, the whole having been derived from the basalts and associated tuffs. This material extends southward over flat land to the edges of the gullies of George's and Tallowa Creeks, these gullies being essentially post-basaltic features. A similar remark is equally applicable to the level, swampy valleys in which Barber's Creek heads.

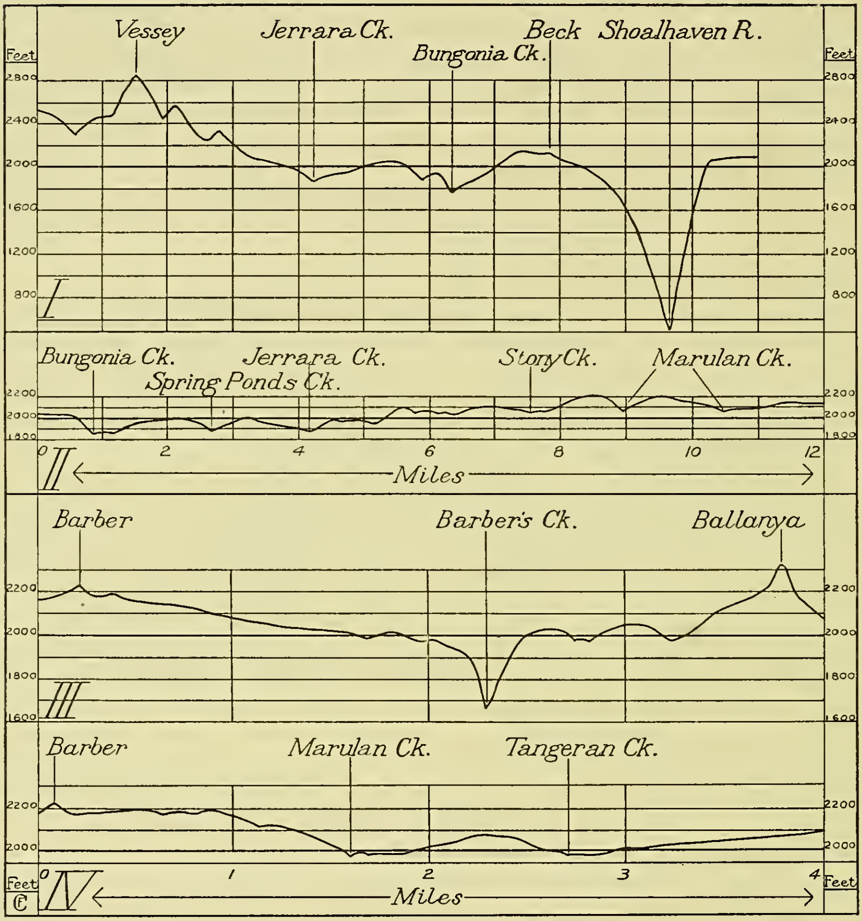
It would appear that swamps existed on the pre-basaltic surface about the (modern) elevation of 2,200 feet and, after the extrusion of basalt and the formation of the bauxite horizon at this level, Barber's Creek has gradually reduced its headwater country in elevation and retains its original swampy nature in parts, whilst originally similar country to the south-east has been drained and dissected by steeper streams flowing to Tallowa Creek.

Looking down the valley of Barber's Creek from Warrima Trig. Station, a gentle and rather indefinite slope westward beyond Tallong is noticed, leading to the granite plains toward Marulan. Certain youthful features are developed on the floor of this valley, the main head streams having steep banks and cliffs on their northern sides. Their southern slopes are, however, much gentler, and the valleys have a slightly asymmetric character. The lowest point noticed on the western side of the Warrima basalt is on the base of the more northern isolated mass at 2,150 feet. Thus the original pre-basaltic slope from this part of the tableland to the granite plains at 2,000 feet must have been quite gentle.

Taken as a whole, the upper valleys of Barber's Creek show the higher levels being attacked by streams based on 2,000 feet, although the degree of maturity of dissection reached is not so great as in the case of the head streams of Uringalla Creek. Still, the divide between this part of the system and Digger's Creek is quite low, being just below 2,100 feet.

iii. *Barber's Creek–Western Valleys* (Plate vi; Text-figs. 3, 4, 5, 8).—Passing down Barber's Creek from Tallong the topography changes abruptly. That part of the stream which flows southward drains a valley two miles wide, lying between dissected strike ridges of ancient rocks (Text-fig. 4). Proceeding southward, this valley widens out to form a considerable plain extending for many miles on the western side of the Shoalhaven gorge.

There are three tributary streams from the west—Tangeran and Marulan Creeks, and the indefinite stream which drains the flats lying east of Marulan. The latter heads between Barber and Shepherd Trig. Stations, and its upper courses are cutting back slowly into the low watershed, giving a gently-rounded topography. Proceeding down the valley towards Barber's Creek a level plain at 2,000 feet is crossed, which is bounded on the north by a long, straight conglomerate ridge. The plain is covered with sandy and gravelly wash and the stream courses are, for the most part, quite indefinite. Going southward across the railway one passes on to a gently undulating slope, which falls from the metamorphic ridge on the west into Barber's Creek. Granite tors and low knolls are features of the landscape which, in turn, give place to the broad valleys of Marulan and Tangeran Creeks.

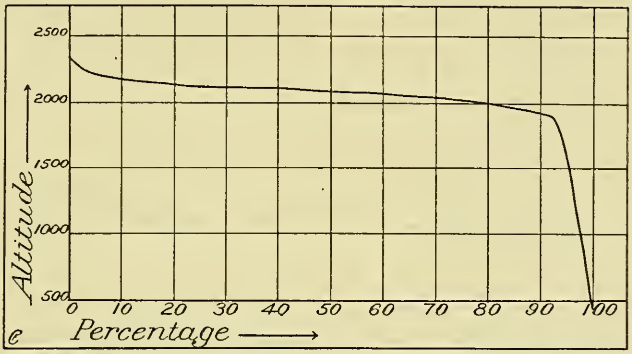


Text-fig. 4.—Profiles: i. Showing the residuals, the Shoalhaven Plain and gorge; ii. Marulan to Bungonia, showing the upper slopes, the 2,000 foot plain and modern valleys in the plain surface; iii. Valley of Barber's Creek; iv. The Barber ridge and tributaries of Barber's Creek. Vertical exaggeration of i and ii = 8·8; of iii and iv = 5·9.

The ridge on which Barber Trig. Station is situated forms a contrast to the surrounding country. Owing to its steeper and more rocky nature, combined with the poorness of its soil, it has been left uncleared, and stands out sharply above the surrounding clear plain. Head streams of Marulan Creek rise in gentle valleys on three sides of this ridge, those going to the east and south falling gently to the main stream, whilst those on the western side lead to considerable areas of barren flats.

In these level valleys the soil covering on the lower slopes is up to 15 feet thick, the surface portion being light and sandy whilst the bottom portions are clayey, and contain a basal layer of pebbles up to 3 feet thick. Soil from the weathering hillsides has drifted over the pebble wash of the original stream beds. Above the 2,000 foot contour the pebble layer is not prominent, and the wash is only about 5 feet thick, whilst below 1,900 feet the streams run into gorges leading to Barber's Creek. Following the destruction of the original trees, the ravages of rabbits and the stocking of the country, these areas of drift along the stream courses are being eroded rapidly, and the good land is being invaded by a network of gullies.

One of the most striking features of Marulan Creek is its great erosive power in time of flood. The channel is from 10 to 30 yards wide and, for the greater part of its length, it is strewn with rock fragments. Cubes and more irregular pieces of fresh granite with edges up to 2 feet have been torn from the stream bed, and are carried freely by flood waters. The ruling grade of this stream is 1 in 90. Tangeran Creek is similar to this stream, and both are notable for the precipitous gorges through which they fall to the main stream.



Text-fig. 5.—Average Profile for the basin of Barber's Creek. Altitude is shown in feet above sea-level. The total area concerned is 33·4 square miles, and the graph demonstrates the first stage in the dissection of a mature tableland surface, the steep lower slope representing the canyons which have been cut as the result of recent uplift.

Falling to Barber's Creek from the east there are small streams which are similar to those on the western side, the most notable being Dog Trap Creek. This rises on clay flats to the east of Ballanya Trig. Station, and passes across the ridge line in a narrow, mature valley. Its course over weathered granodiorite is true to type, but its sediments are better differentiated than those of Marulan Creek. A typical section 800 yards above Barber's Creek reveals 8 feet of sandy drift resting on 1 foot of small quartzite pebbles and angular fragments which, in turn, overlie white clay. The small streams further south are similar, but lack the quartzite pebbles in their drift.

Turning to Barber's Creek itself, we find the greater part of this section entrenched in a deep gorge whose sides are perpendicular in places. The head of erosion is marked by waterfalls aggregating 300 feet in height but, above the head of the falls, a narrow trench 100 feet deep extends back for some 300 yards into the undulating valley. This would appear to be due to local vertical down-cutting resulting from the increased horizontal velocity of the water as it approaches the steeper grade downstream, although the grade in the section so affected only changes very gradually. This feature is found above most of the waterfalls on the edge of our plateau scarp.

Having obtained some idea of the appearance of this section, we may now survey its physiography. The higher tableland levels at 2,200 feet which are found to the east only exist here as isolated ridges. The predominant level is that based on 2,000 feet (Text-fig. 5), including those plains by the railway at a slightly lower elevation. The country at the heads of the western tributaries rises gently to 2,100 feet, but is part of the same gentle slopes. The plain has been cut into by a series of gentle valleys whose floors are covered with deep well-differentiated drift, itself indicative of mature and stable conditions. Remains of silicified sands and conglomerates occur on the eastern side at 2,000 feet, and would appear to have been associated with the basalt flows, thus giving an indication of the age of part, at least, of this valley.

The present maturity of the landscape when compared with the country further east is closely associated with its geology for, as Browne (1928) again emphasizes, granites may weather to a considerable depth before actually being subjected to the active forces of erosion. Such a process has not affected the surrounding sedimentary rocks so, when the plain at 2,200 or 2,300 feet was first subjected to erosion, great quantities of the weathered granite would be readily eroded, leaving the chemically inactive rocks as residuals.

But, despite this variation in the amount of denudation, the streams operating on different rocks have cut down to a common level, from 200 to 300 feet below the surface of the original plain, and the great widening of the lower valley of Barber's Creek and the valleys of its tributaries has been accomplished since this level was reached. This process is still continuing, and even the porphyries to the west of Marulan are being attacked readily because, in many places, their groundmass has been decomposed to a soft clay to some depth below the surface.

This part of the area is of particular interest in that the older plain, now at 2,200 feet, is well preserved in the horizontal sedimentary rocks, whilst its distinctive character in the rocks liable to extensive pre-erosional rotting has been largely destroyed. The wide valleys may be classed as "mature"—or even, perhaps, as part of an incomplete peneplain—but the narrower valleys about the head of Uringalla Creek are quite as ancient, and the streams have cut their divides down almost to the 2,000 foot level, which is the common local base.

iv. *Digger's Creek.*—The greater part of the course of this small stream is in a deep gorge. The principal drainage area is crossed by the Tallong to Caoura road, where the deep soils covering the slopes between 2,000 and 2,200 feet store up a good deal of water and give a small permanent flow. On the western side, Dog Trap Creek takes part of the drainage which one would expect to go into Digger's Creek, especially as the gorge of the latter has almost reached the indefinite, soft divide which separates the two runs.

At the point where the stream begins to fall there are beds of level alluvial material containing somewhat rounded fragments of quartzite from the hillsides to the south-east. This material has a thickness of 5 to 10 feet, and its surface at 1,990 feet comes right to the edge of a trench, 100 feet deep, which marks the commencement of the gorge. Above this fall in the modern stream-bed there are small aggradation flats in the concave stream bends between 1,960 and 1,990 feet, from which a little gold has been won.

On the western or Ballanya side the local 1,990 foot level is continued as a pebble horizon (Plate vi, inset). The pebbles are up to 2 feet in diameter and consist mainly of brown sandstone and quartzite of ellipsoidal shape which have been derived from solid conglomerate resting on an agglomerate base at 1,950 feet. Underlying rocks are slates and quartzites, and angular masses of these pass upward into the horizontal strata and some of the pieces, weathered from the surrounding material, are found in the small stream channels. Above the conglomerate there is a fine-grained ferruginous sandstone and grit containing small pieces of white reef-quartz above which, and up to 2,050 feet, the slopes are covered with sandy soil containing quartz and quartzite pebbles up to 5 inches in diameter.

This deposit probably represents an outlier of the Upper Marine Series, other relics of a slightly different character occurring about the older rocks (Text-fig. 8). Standing on the loose surface pebbles above the gorge of Digger's Creek and looking northward, the pebble and conglomerate bed is seen to be enclosed on all except the gorge side by a low bank. Part of this is a spur from Ballanya Trig. Station, and forms the divide between Digger's and Dog Trap Creeks. Excavations for a water supply tunnel across this ridge at 2,050 feet have disclosed the presence of the older folded slates, which are weathering to a white clay, and which are strewn over by quartz drift as one approaches the head of the gorge.

Passing from this ridge down the valley of Dog Trap Creek one finds the lowest part of the divide at 2,030 feet, and the westward fall is over flats of fine clay. A uniformly gentle fall leads to the edge of the granite country at 2,000 feet, where the stream flows over a bar of white quartzite to emerge on the plain.

The gorge of Digger's Creek is steep-sided and rough, and the activity of the stream has resulted in the deposition of a bank of detritus at its junction with the Shoalhaven River. The considerable size of this gorge when compared with that of Barber's Creek—a much more powerful stream—is readily accounted for by the fact that it is cut parallel to the strike of the Ordovician slate in which it exists, whilst the gorge of the latter stream is cut in massive and comparatively fresh granodiorite.

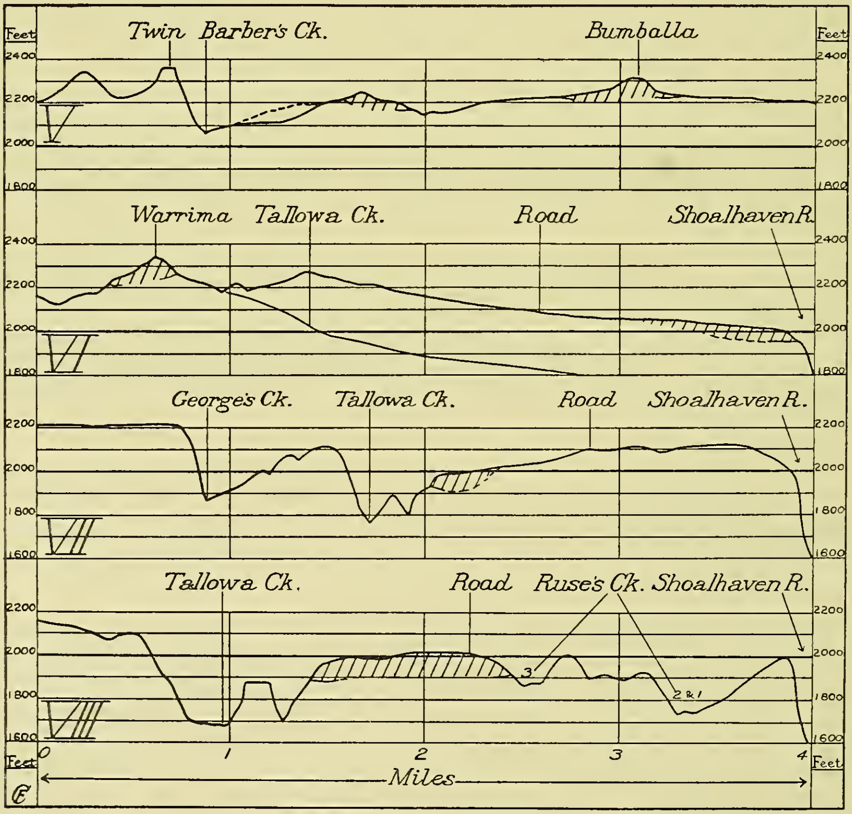
The main points of note in this section are the conglomerate relics, which had been described by Woolnough and Taylor (1906) as fairly recent stream gravel, and the flats at the head of the stream formed as the result of erosion in the edge of the Permian series. In fact, the periphery of these strata is marked by a continuous valley extending northward to the Wollondilly basin.

v. *The Area of Basalt Flows* (Plates v, vi; Text-figs. 3, 6 and 10).—The basalts of Warrima and Bumballa probably represent original centres of extrusion, and there may be others in the neighbourhood of Badgery's Lookout (*fide* Woolnough, 1909, and Geology Dept. of the University). There is a possibility that some basalt came from the direction of Warrima and contributed towards the flow which extends from Badgery's Lookout to Caoura Trig. Station (Plate v), but, so far as physiography is concerned, the origin of the Caoura flow is not a matter of great importance.

The head of Tallowa Creek occupies a broad valley cut in the eastern flank of the Warrima basalt but, near Bumballa, the stream runs into a rough gully

200 feet deep which is surmounted by sandstone cliffs up to 60 feet high (not shown on the contour map). Small tributary runs have formed bays on either side of the main gully, and these conditions continue until George's Creek is reached. On the northern side of its valley is a steep bank, but the southern slopes are quite gentle (Text-fig. 6). This valley is incised 300 feet below the bauxite level, and its width is due to its being eroded in soft sandstones and shales.

Below this stream Tallowa Creek flows into a characteristic gully. On its northern side is a flat hill at 2,100 feet which slopes uniformly into the creek. To the south are sandstone terraces at 1,800 to 1,950 feet, which are surmounted by basalt. Passing a mile downstream the basalt comes almost to the creek in a place where both sides of the gully are quite gentle. Here there is also an extensive terrace on the northern side, which ends abruptly against a steep bank 150 feet high. The second hill on this side forms a distinct peninsula and, on either side of the gully, terraces are well developed between 1,850 and 1,900 feet. Here the gully is becoming a gorge, and the horizontal sandstones are under-



Text-fig. 6.—Profiles across the eastern basalt flows. Note the 2,200 foot plain, the Twin residual, the basalt-filled valley and the valleys due to post-basaltic erosion. Basalts are hatched. Vertical exaggeration = 5·9.

lain by hard porphyries through which the stream is cutting. Essentially similar conditions continue eastward to the junction of Tallowa with Bundanoon Creek and the Kangaroo River. Four miles east of Caoura Trig. Station the terrace has fallen to 1,500 feet, and the gentle fall continues eastward.

Let us now consider the actual basalt flow. The western end is a level plain and, where small streams falling to the Shoalhaven have trenched it, they reveal the base to lie at, or possibly below, 1,950 feet, giving an existing maximum thickness of at least 130 feet. As the result of erosion, there have been developed at this end steep banks which stand above the cliff edges of the Shoalhaven gorge, though a little back from it. Off the edge of the flow there has been considerable contact metamorphism giving a glassy quartzite up to 6 feet in thickness, as in the creek bed to the east of the Lookout. These contacts are valuable as defining the limits of the valley which the basalt has filled and are, in general, close to the former edge of the flow. Remnants of lateral valleys are preserved in places. This part of the flow is of square shape with sides a mile in length.

Continuing eastward parallel to Tallowa Gully the width of the flow diminishes, although the generally plain character of its surface persists between converging hills. At the first constriction the basalt is only 400 yards wide, although contacts point to a former width of 700 yards. Here a ridge of soft sandstone and shale rises southward to a height of 140 feet above the basalt surface. Still proceeding east we find that three transverse streams have cut right across the flow, giving two isolated masses with an appearance not unlike that of huge pancakes. The line of maximum thickness here trends south-east and north-west and, although the absolute thickness of the basalt is obscured by drift from the steep crowning banks, it is not less than 150 feet, and the lowest part of the base is, at most, 1,850 feet above sea-level.

Passing these isolated areas, the line is found to continue for two miles to Caoura Trig. Station and the flow preserves a fair width, although it is almost cut across in places. The northern edge is defined with some certainty by contacts from 1,900 feet upwards, and erosion has apparently removed a maximum width at the constriction. The southern edge is by no means as certain because, as the quartzite hill near Ruse's Creek (1,700 yards SW. of Caoura Trig.) shows, erosion has played a considerable part. The maximum thickness of the basalt seems to be 200 feet near Caoura Trig., where an almost precipitous bank overlooks the head of Bullangalong Creek. The outlier to the south-east of the trigonometrical station and immediately above the Shoalhaven cliffs is probably a branch of the main flow, which points towards the place where Bullangalong Creek crosses the cliffs of the Shoalhaven gorge. Isolated relics further east ("White's Selection") also point towards this locality.

The basalt is thus found to occupy a definite valley, both commencing and ending above the main gorge (Plate v). The original valley is well preserved, and exists to the present day as a definite topographic feature through the greater part of its original length. Between this valley and the Shoalhaven cliffs is an area of plain country between 2,000 and 2,100 feet, which has been maturely dissected by the head streams of Ruse's Creek (marked 1, 2, 3 and 4 on the map), and to a much less extent by other smaller streams.

Of the heads of Ruse's Creek, 4 and the upper parts of 2 are lateral streams; 3 may have been a transverse stream, whilst 1 is not connected with the basalt.

The four valleys unite to form a broad, irregular amphitheatre, and they are mature to 1,750 feet (Text-fig. 10); 1, 2 and parts of 4 are well graded with alluviated courses and stretches of swamp, and they flow in U-shaped valleys. On the south of 1 is a line of hills overlooking the river, and cut off sharply by great precipices; 1 and the Shoalhaven River are horizontally equidistant from this line of hills.

The western head of Bullangalong Creek flows in a rather similar valley to the preceding, but its sides are higher and steeper. This section was probably a transverse stream. To the west of Ruse's Creek the land is crossed by gentle stream beds which only become entrenched near the edge of the cliffs.

We may now consider the development of the topography, beginning with the more recent forms.

The valleys to the south of the basalt flow are necessarily post-basaltic. This also applies to the transverse valleys falling to Tallowa Creek and to the sandstone benches along that stream. It may also be stated that the valley now occupied by basalt originally fell into the Shoalhaven about the vicinity of the modern Bullangalong Creek, and that the upper part of Tallowa Creek—at least that part within the basalt flow section—is more recent than the basalts. This latter is, in fact, separated from the wider and lower parts of the terraces by a neck of high land to the east of Caoura.

In the case of the mature and sub-mature valleys above the river, we have a clear differentiation between them and the great gorge to which their streams fall, and their lower parts are now being attacked with considerable force, causing the recession of cliffs and waterfalls and the development of more youthful features.

The basalt flow itself is seen to occupy a linear valley whose original character can be inferred from the maps and sections (see Text-fig. 6). In form it was approaching maturity, and would appear to have resembled the upland valley of Digger's Creek in having broad and level sections connected by a narrower channel. The steep bank on the northern side of Tallowa Creek would appear to be the old valley side considerably steepened by erosion. Its recession has not been uniform, but the presence of outstanding "capes" is probably due to locally hard patches in the surface covering of sandstone. To get the pre-basaltic profiles we may take a gentle slope from the 2,200 foot plain on the northern side to the present northern edge of the basalt, so that it coincides with the inward-dipping contact quartzite. The southern side is still fairly well preserved in its central section, and the destruction of the original northern profile measures the post-basaltic erosion.

We have thus come back to pre-basaltic conditions, where the 2,200 foot plain was trenched by a simple valley to a depth of 350 feet, whose sides were being attacked by tributary streams. That this process had not gone very far is shown by the ground plan of the basalt-filled valley, which has no important branches. On the higher plain to the north erosion has also progressed in two stages. The head of Tallowa Creek is in a mature post-basaltic valley which is now being attacked by the streams with the resultant formation of a steep gully (Text-fig. 6). The 2,000 foot level is represented in the neighbourhood of Badgery's Lookout, but not so definitely as in the case of Barber's Creek. The basalt-filled valley with increasing depth eastward seems to represent a distinct phase in erosion below 2,000 feet, this stage having been continued towards maturity by Ruse's and Bullangalong Creeks.

Using 2,200 feet as zero, a comparison between the physiographic forms dealt with up to the present may be made:

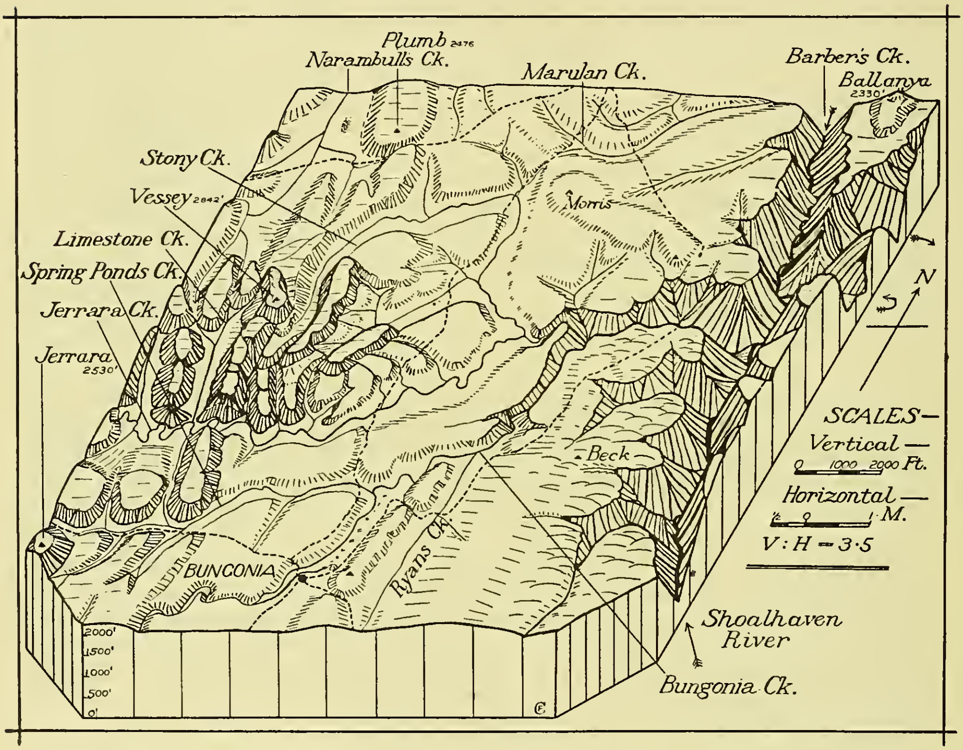
Feature.	Cycle or Part Cycle.	Vertical Height.	Comparative Age.
Residuals	1	+150′	Pre-basaltic
Tableland	2	0	Pre-basaltic
Valley of Barber's Creek	3	−200′	Pre-basaltic (Since extended)
Digger's Creek	3	−160′	Pre-basaltic
Valley between Lookout and Caoura ..	4	−350′	Pre-basaltic
Terraces of Tallowa	4	−400′	Post-basaltic
Ruse's and Bullangalong Creeks	4	−500′	Post-basaltic
Upper levels of Tallowa Creek, 4 miles E. of Caoura	4	−700′	Post-basaltic
Canyon of Shoalhaven River	5	−1900′	Post-basaltic

Of these cycles or part cycles of erosion, only traces of the first remain; the second was completed, and its effects have been largely obscured by the third. The fourth and fifth are notably incomplete, the effect of the former in particular virtually being confined to the country east of Barber's Creek, and being more pronounced as one goes further eastward. The conclusion is that erosive forces have operated towards the east and have either not been applicable to the west on account of essentially different conditions of elevation, or did not have time to push further westward before the cutting of the canyons as they exist at present. The remarkable topographic uniformity of the tableland surface between the Wollondilly River and the Illawarra coastal highlands, when taken in conjunction with the forms already described in this paper, certainly suggests uniform normal uplift, and the balance of evidence is in favour of the latter alternative of extra part-cycles towards the coast.

There is also a definite suggestion that the last stages in the elevation of the plateau involved an essentially constant uplift of the order of 1,000 feet, thus allowing for the difference between the base-level of the modern gorges (i.e. sea-level), and a former base-level now represented by the lowest limits of part-cycle 4. In other words, base-level has remained constant within narrow limits, but the old surfaces have been uplifted.

In all this it must be remembered that Caoura is only 25 miles from Nowra, and although that town is 15 miles from the sea, the nature and extent of the deltaic deposits below it suggest that the Shoalhaven River at Nowra has been at sea-level over a very long period of time, and the forces of erosion have had ideal conditions for their attack on the immediate hinterland, from which the softer surface material has been removed during pauses in the uplift, giving a distinctive series of part-cycles of erosion which disappear as one goes westward.

vi. *The Bungonia Creek System* (Text-figs. 4, 7, 8, 10).—On the western side of the Shoalhaven gorge there is an extensive plain up to 8 miles in width which is dominated by high residual ridges. The river itself is deeply entrenched in this plain, and some of its tributaries have cut sharply into the sides of the main gorge. The westward ridges are broken and rocky but, as most of them have been breached by streams, they are by no means inaccessible. It is convenient to discuss these separately from the plain.



Text-fig. 7.—Block Diagram of the Bungonia Creek System. Note the residuals in westward-dipping rocks on the west, the Shoalhaven Plain in the centre, and the modern gorges on the east.

a. The Residual Ridges.—These owe their existence to the hard and resistant nature of the quartzite of which they are composed. The strata dip west at an average angle of 45 degrees, so the phenomenon of alternating dip slopes and scarps gives equal eastward and westward slopes. Interbedded with these harder rocks are less resistant shales and slates and a bed of limestone, which have been generally—although not uniformly—weathered away to form a series of deep valleys. The topography thus suggests a series of rather sharp waves whose axes are parallel to the strike and are, therefore, meridional.

The master ridge lies to the east of Gundary Creek and includes the heights of Gundary and Towrang Trig. Stations. In structure it is synclinal, with the steeper limb on the eastern side. It forms the western watershed of Jerrara and Bungonia Creeks and separates those streams from the Wollondilly waters although, near Towrang, it is entirely within the Wollondilly system. On the eastern side of this master ridge, which rises to 2,845 feet, there are three lower ridges varying from 2,400 to 2,530 feet. They are cut across by the main streams, whose tributaries have eroded deep strike valleys between them. Divides between these latter are quite low and easily travelled. Passing eastward we reach another high ridge, highest at Vessey Trig. where it reaches 2,842 feet, and falling both to the north and south. Here the prevailing quartzite is relieved by the presence of fossiliferous breccia.

The Vessey ridge is buttressed on its eastern side by two shorter and lower ridges at 2,600 and 2,300 feet respectively whose central points are joined by lower cross ridges forming the starting points of short meridional valleys. Those on the north fall to Stony Creek, whilst the more southerly enter the valley of Jerrara Creek. These ridges mark the eastern boundary of the quartzite strata, and where the zone of intrusive quartz-porphyries is reached, the country falls in a series of poorly-defined terraces at 2,200 and 2,100 feet to the Shoalhaven Plain.

Of the streams which flow through the residual country Jerrara Creek is the most notable. Rising on the eastern side of the master ridge in a flat-bottomed valley at 2,250 feet, it flows eastward past the three lower ridges, and crosses the western limestone belt at 1,960 feet, having come through a mature valley. Looking upstream from the limestone belt at Pearce's homestead, a distinct terrace at 2,100 feet is observed, about 100 feet above the modern stream flats. This higher level extends to 400 yards on either side of the stream, and forms a notable minor feature.

A small stream comes along the limestone from the west of Vessey Trig., and flows through a flat-bottomed valley a mile and a half long. Only the lower 700 yards are actually in limestone, which disappears northward and is replaced by shales. Where it does occur, its eastern edge is marked by bluffs of impure haematite and limonite rising to 30 feet above their bases. These are the result of concentration of oxides of iron from the limestone and neighbouring slates at the base of the westward-dipping limestone, part of which has since been removed by solution. This valley lies between 2,000 and 2,150 feet, and it is separated from Narambull's Creek by a col at 2,300 feet which joins Vessey with the westward ridge at 2,530 feet.

Narambull's Creek falls gently through a widening valley to Shelley Flat on the Southern Highway, and past there to the Wollondilly.

The western limestone belt can be traced to Spring Ponds Creek, about 2 miles south of Jerrara Creek, between which two streams it and the associated slates are responsible for a lower place in the divide at 2,160 feet. Below this limestone Jerrara Creek passes on to slates and quartzites. The hills close in and the stream flats and terraces disappear for some hundreds of yards (Plate iv, fig. 2) as the stream crosses the hard strata of the Vessey mass, which stands up grim and solid on the northern side. After passing this harder bar at a gentle grade, the stream flows into a wider valley with flats up to 400 yards wide on the left bank at an elevation of 1,950 feet. These continue downstream for a half-mile, the country on either side becoming progressively lower. Then once again the valley narrows, and the flats almost disappear as the stream cuts through the hard western edge of the porphyries. These conditions continue for half a mile, after which the stream emerges on to extensive levels at 1,920 feet. Here it follows a gentle course through sandy drift about 4 feet deep overlying beds of water-worn pebbles, consisting of quartzite and quartz-porphyry. The material is roughly stratified, and is being eroded rapidly following the removal of trees from the banks. From this point there is a gentle fall past the Bungonia road, this part of the stream being in a late mature valley on the Shoalhaven Plain. It will be seen that the topography of this creek is that of an ancient stream which has been flowing across rocks of vastly differing degrees of hardness over a long period of time.

On the northern side of the Vessey mass are the valleys of Stony Creek at 2,200 feet which, like those of Jerrara Creek, have been determined in their upper courses by the prevailing rock strike. The main stream turns south-eastward to fall across the Bungonia road at 2,030 feet to its junction with Jerrara Creek at 1,800 feet. The Vessey ridge forms its western divide, and the ridges between the tributaries rise from 2,250 feet on the east to 2,500 feet on the west.

The heads of Spring Ponds and Bungonia Creeks are also in the ridge country. The former rises in level valleys between 2,000 and 2,050 feet, the two main heads being separated by a ridge 200 feet higher. Its main course is across the plain. Many of the head streams of Bungonia Creek also rise in level valleys in the ridge country at 2,100 feet, but they flow past the ridges where the latter are much lower and less impressive than in the case of Jerrara Creek. By far the greater part of the course of this stream lies on the plain, across which it flows in a shallow trench up to 100 feet deep.

b. The Shoalhaven Plain.—Looking eastward from the heights about Vessey Trig., an extensive plain is seen to extend on either side of the Shoalhaven River, that part on the western side of the gorge being a little lower than the eastern section. This plain includes the lower parts of the basins of Barber's, Bungonia and Nerrimunga Creeks, and is marked by low relief and very subdued divides. It forms a striking contrast to the ridge country and, upon examination, it discloses a long and varied history.

The dividing ridge between Barber's and Stony Creeks rises to 2,265 feet at Morris Trig. Station, although the greater part is about 2,200 feet. The slopes of this ridge are gentle, and quite characteristic of granite country. The valley of Stony Creek falls uniformly to the south of this ridge and the course of the stream at 1,850 feet half a mile above its junction with Jerrara Creek discloses an entrenchment of the order of 100 feet in the level surrounding plain. The stream course is rocky, and is marked by small aggradation flats and boulders.

Jerrara Creek follows a very broad valley after emerging from the hills, and falls from 1,900 to 1,800 feet before plunging into a ravine through which it falls to Bungonia Creek. On either side of this stream the ground rises gently to form a plain at 2,000 feet—the general level of the "Shoalhaven Plain" (Text-fig. 4). This surface extends southward past Bungonia, where it is drained by Spring Ponds and Bungonia Creeks, the former being entrenched nearly 150 feet in a broad valley at its junction with the latter. The course of Bungonia Creek is sufficiently varied to deserve special attention.

When the limestone belt is crossed above Bungonia at 1,900 feet, the stream flows in a mature valley in the 2,000 foot plain. The limestone is associated with sandstone, quartzite, grit and shale, which rest on granite and dip westward from 10 to 20 degrees, forming a low bluff on the right bank. Entering the zone of intrusive rocks the valley becomes narrower, but the stream continues to fall gently in a wide, sandy channel to 1,860 feet at Bungonia bridge. Beyond here the valley broadens again, and continues through weathered granite past the junctions of Spring Ponds and Ryan's Creeks, the latter entering about 1,770 feet. Half a mile further down is a sharp bend to the north-west, and the stream falls 50 feet to an elevation of 1,710 feet through a narrow ravine cut in dense felsite. This entry into fresher and more resistant rocks is marked by a corresponding increase in the steepness of the valley sides, although the fall during the next mile is only 50 feet and the floor of the valley is 100 yards wide. At this stage the depth of entrenchment is almost 300 feet, but only the lower half is represented by very steep slopes.

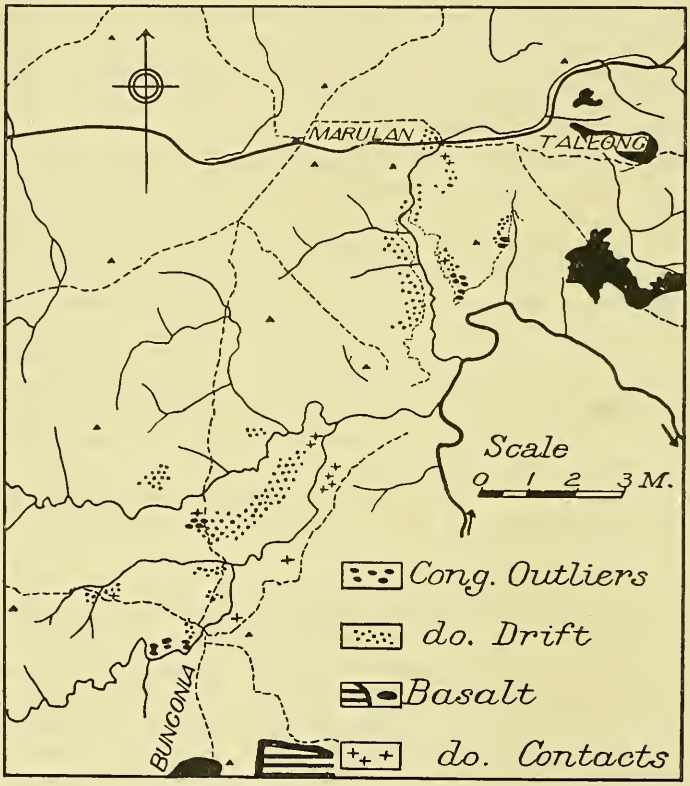
There is a fall of 160 feet in the next half-mile through a narrowing and steepening gorge, which finally becomes inaccessible with precipitous sides when the stream has fallen to 1,600 feet. Above the junction of Jerrara and Bungonia Creeks there is a notable series of waterfalls on either stream, and the ravines above the falls are deep and exceedingly narrow. Below their junction the waterfalls continue, but the gorge has assumed a more usual "V" shape with a depth of some 1,400 feet above the eastern limestones. Where it crosses the main belt of (blue) limestone, almost the whole depth of the gorge is represented by a magnificent ravine with perpendicular sides, but it widens considerably towards the Shoalhaven. A mile below the limestone the stream makes an accordant junction with the Shoalhaven River somewhat below 450 feet above sea-level. In time of flood the power of these streams is enormous, but they only cut downwards and backwards comparatively slowly through dense and unweathered rocks. In the stream channels the rocks are smoothed and polished by the abrasive action of water-borne material.

Ryan's Creek, a tributary of Bungonia Creek, rises near Chapman Trig. Station and follows the blue limestone northward through a broad U-shaped valley. Between the Inverary Park road and Bungonia Creek, a distance of 4 miles, it falls 130 feet. The ridge separating it from Bungonia Creek is capped with ancient sandstone, and has an elevation of 2,000 to 2,050 feet. Bungonia Creek cuts across the ridge from the west just above the junction of Ryan's Creek, and swings out of the limestone about a mile further on, so the strike ridge to the west of the limestone is cut in two by this stream, the eastern half continuing to the Lookdown. Near the Lookdown, the limestone belt is marked by a number of sink-holes and a series of small caves.

On the eastern side of this limestone belt, and separating it from the slopes leading to the Shoalhaven, there is a ridge composed of chert and jasper at an elevation of 2,100 to 2,150 feet. This extends southward from the head of Beck's Creek, and apparently represents part of the crumpled Ordovician formation although here, on its western side, the Ordovician zone is much less twisted and broken than is the case below Barber's Creek on the Shoalhaven. The general dip on this western extremity is westward. The limestone itself dips westward at 45 to 55 degrees, but at some places, as on the Inverary Park road to the east of Ryan's Creek, it rests upon slates dipping very steeply eastward.

Ridges leading from this line of hills towards the Shoalhaven exhibit level stretches at 1,900 feet as they approach the river. This terrace has, of course, been greatly dissected, but it is a uniform feature on the western side of the river for some miles above the Lookdown, and might possibly be correlated with the eastern part of the valley of Jerrara Creek or the basalt-filled valley of Caoura.

This part of the Shoalhaven Valley is, then, a plain at 2,000 feet, in which broad, mature valleys have been cut to a maximum depth of 200 feet. It has been trenched by the canyons of the Shoalhaven and tributary streams, the latter of which are now cutting back from the main gorge.



Text-fig. 8.—Map showing conglomerate relics, contact quartzites and basalts. Compare with Text-fig. 2.

c. *Conglomerates and Contact Quartzites* (Text-fig. 8).—The plain has two features which make it especially noteworthy in the remains of pebble conglomerates and the presence of occasional glassy quartzites similar to those found in contact with the Caoura basalts. The quartzites have already been mentioned, but further details might not be amiss. The principal occurrences are:

1. Capping a hill 700 yards NW. of Bungonia Trig. Station. Elevation 2,000 feet. Thickness 10 feet. Extent (approx.) half an acre.
2. On Bungonia-Marulan road, 800 yards south of Jerrara Creek. Quartzite and indurated conglomerate on the hillside at 1,950 feet cover about an acre and a half. The covering is superficial, and overlies white clay from porphyries.

3. To the east of Bungonia Creek between 1,870 and 1,970 feet. The occurrence is about the western edge of the limestone a mile SW. of the Lookdown. The meridional length of the occurrence is 500 yards, and the maximum width 300 yards. The thickness is doubtful, but must be several feet in places.
4. On the ridge between and above Bungonia and Jerrara Creeks at 1,950 feet. The outcrop has a length of 600 yards, but the width rarely exceeds 20 yards. It is replaced towards the south by quartz pebble drift.
5. On hillsides to the west of Ryan's Creek, and an erratic on the plain to the east. Elevation 1,830 feet. These pieces are probably the product of weathering from higher levels, the material on which they originally rested having been dissolved away.
6. Pieces of silicified conglomerate in the valley of Spring Ponds Creek on the Goulburn-Bungonia road. Elevation 2,010 feet. The occurrence is not extensive.

All of these occurrences are purely surface features developed under favourable conditions, either on sandy soil, sandstone or weathering conglomerate. They are entirely distinct from the partially altered sandstones found near the top of the granitic intrusion, or the massive quartzite contact series found on the sides of the intrusion at a considerably lower level. A fine example of the latter is a greenish-quartzite bluff 100 feet high which overlooks the junction of Bungonia and Jerrara Creeks from the north-west.

It seems certain that the six occurrences noted are similar in origin to those near the Caoura flow—they owe their existence to basalt flows which have passed over the old land surface, here about 2,000 feet. Their closeness to ancient streams, together with the presence of elevated basalts at Inverary Park with a base at 2,060 feet overlooking the valleys of Ryan's and Bungonia Creeks, adds weight to the suggestion that these quartzites were associated with now-eroded basalt flows, and mark a part of the late Tertiary land surface.

Turning now to the conglomerate relics, we find them to be much more widespread, although the greater part is probably a surface screening only which has come down from disintegrated strata at a somewhat higher level in the natural process of vertical wasting. The principal occurrences are:

1. Conglomerate strata and drift on the divide between Jerrara Creek, on the one hand, and Spring Ponds and Bungonia Creeks on the other. The elevation varies from 2,010 feet to 1,950 feet (and may be even lower) on the Bungonia-Marulan road. Portion of this material at the lower level has been indurated. The remainder rests on porphyritic rocks and appears to be horizontal. It contains pebbles of white reef-quartz, brown and grey quartzite, grey chert, jasper and quartz-porphyry—all locally derived material. The pebbles are somewhat rounded, and their major diameter varies from one to six inches. This drift continues northward along the ridge between 1,950 and 2,000 feet, and extends over a length of three miles and a half. Similar material is found on the opposite side of Spring Ponds Creek at a similar elevation.
2. Pebble conglomerates are found above Bungonia Creek at 1,960 and 2,030 feet. They are ferruginous, and contain quartz, sandstone and quartzite pebbles with a diameter up to 8 inches. In general they are well rounded and the material, on the whole, resembles that found south-west of Ballanya Trig. Station. The surface upon which they rest is of slight relief, and consists of decomposed granite overlooking the left bank of the stream a short distance below the western limestone belt.

3. Pebble beds are found at Spring Ponds Creek on the Goulburn-Bungonia road at an altitude of 2,000 to 2,020 feet. This material occurs near the junction of the two head-streams of Spring Ponds Creek, and at first sight looks like a bank of stream drift. Closer examination reveals the presence of cemented pebbles and fine-grained sandstone containing small quartz pebbles and gravel in places. A distinct horizontal bedding is visible. The larger fragments and pebbles are of quartzite, and the latter are ellipsoidal in shape, being unlike the rounded fragments or pebbles of similar rock found in the modern stream beds of the tableland or in the gorge of the Shoalhaven.

The conglomerate and drift about the 2,000 foot level would appear to be distinct from the base of the Permian series, which are found with some thickness on the other side of the Shoalhaven, where they form the surface of the tableland rising from 2,000 feet to an altitude in excess of 2,400 feet. Continuing northward from these pebble occurrences, we find similar conglomerate relics existing to the south-west of Ballanya Trig. Station, and on either side of Barber's Creek at an elevation of 2,000 feet. Woolnough (p. 786) recognized the latter and the screening near Bungonia Caves as being "Permo-Carboniferous", but they are confined to a plain level distinct from the rising base of the Upper Marine Series, and have no marked resemblance to the basal beds of those strata. (See also paper ii of this series, when published). The following points may be recognized:

1. The Vessey and Jerrara ridges are old erosion scarps whose bases have been exposed by the removal of newer sediments. Presumably there has been some retreat of their outer edges.
2. The pebble drift and conglomerate extending from Bungonia to Tallong form part of late Tertiary deposits, and the more southerly relics project into ancient indentations, through which streams now flow. This must be taken as a tentative conclusion only, in the absence of definite palaeontological evidence.
3. The western limit of the Permian series is marked by the lines of high residuals, which can be compared with Mts. Walker, Flaherty, Lambie and Gangerang Range in the Cox Valley (Craft, 1928*a*).
4. The 2,000 foot level to the south of the Barber's Creek system represents a peneplain of Tertiary, and possibly of pre-Permian age which has been exposed again by more recent erosion. A similar level continues into the newer strata to the north, and extends over the eastern part of the Wollondilly basin (Craft, 1928*b*) and is, therefore, an erosional feature developed at a regionally constant base-level.
5. It will be noticed that there is no mention of faulting as a possible explanation of the high western ridges. There is no physiographic evidence of faulting in this area, as the description of the "residual ridges" will have shown. Likewise it is not suggested that the various top points of the residual ridges represent relics of ancient peneplains, as the gradual weathering of the post-Devonian folds is amply sufficient to account for the isolated and exceptionally high masses. The highest level to give a peneplain impression is that at 2,500 feet, which is comparable with the residuals in the Tallong area and the eastern Wollondilly at 2,350 to 2,400 feet.

The existing land forms in the Bungonia Creek system may be correlated with those around Tallong, again using 2,200 feet as zero:

Locality or Feature.	Cycle or Part Cycle.	Elevation.	Age.	Remarks.
Residuals	Ancient	+ 500′	Permian	Probable.
Ridges, Upper Jerrara Creek	1	+ 300′	Pre-basaltic	Doubtful.
Beck, Morris and Cowhole Ridges	2	0	Pre-basaltic	Depends on correlation of land forms in horizontal and folded rocks. Doubtful because of closeness to Shoalhaven Plain.
Shoalhaven Plain	3	− 200′	Pre-basaltic	Extended very little in more modern times.
Higher Terrace, Upper Jerrara Creek	3	− 100′	Pre-basaltic	
Valleys of Jerrara, Spring Ponds and Bungonia Creeks ..	4	− 300′	Post-basaltic	Average value for middle part of plain section.
Deep Gorges	5	− 1700′	Post-basaltic	Extreme value.

vii. *The Shoalhaven Gorges.*—The upland country supplies the most valuable physiographic material, but the deep gorges are also instructive. Between Bungonia Creek and a point opposite Caoura Trig. Station the river falls from 420 feet to approximately 350 feet. It flows in a narrow, rocky channel up to 60 yards in width, but where conditions are favourable lateral erosion has given flats or terraces on the concave bends which are covered with old flood-drift. The flood terrace rises to 60 feet above the river-bed immediately above very sharp turns, and consists of rounded pebbles up to 2 feet in diameter overlain by smaller rock-fragments and, in places, by a superficial covering of sand. In the actual stream-course the nature of the boulders found is largely controlled by the tributaries. Near Bungonia Creek the pebbles are small and consist largely of limestone and slate brought down by that stream and the river itself. Barber's Creek rolls huge boulders of granodiorite up to 4 feet in diameter into the river bed, and these constitute the greater part of the stony material during the next four or five miles. In time of flood these masses move along the rocky channel and form a great mill, which grinds and crushes all the smaller and softer material washed down by the torrent.

The lateral movement of the river has been greatest at the incised meander below Barber's Creek. Terraces exist 40 feet above the river, and consist of granite pebbles covered with a drift of soil which has, in times past, been cultivated (MacCallum's selection). Some 400 yards below Digger's Creek on the left bank relics of similar material are found 80 feet above the river. Here the river is diverted to the right by a quartzite bar and this, combined with a sharp left-hand turn immediately below, has resulted in the piling up of the highest modern terrace on the right bank immediately above the bar.

Despite its great drainage area (2,400 square miles above this point) the normal flow of the river is quite small, although most of the channel is rendered dangerous by the presence of great boulders.

In considering the sides of this gorge, we are at once struck by the linear cliff lines between Digger's and Bullangalong Creeks on the northern side of the river. These walls illustrate the slowness with which massive horizontal layers in the top position are attacked, provided that they are not underlain by excessively weak strata. Passing upstream, the great bay eroded by Digger's Creek has already been noticed and, continuing southward along the main gorge from that point, the gorges torn in the main slope by Bungonia, Beck's and Spring Creeks make that section difficult to traverse. Again the weakness of the Ordovician structures is shown, as the crumpled and closely jointed strata are readily torn away by stream action. The shales and slates are susceptible to atmospheric influences and crumble readily on exposure, thus undermining the more resistant quartzites. On the eastern side the capping of horizontal sandstone has protected the tableland to some extent, but the absence of notable streams in this part has also retarded the dissection of the canyon sides. Further up the river this condition does not apply.

The rapidity with which the Shoalhaven has cut its canyon is illustrated by two facts. The slopes are very steep, being often inclined more than 35 degrees to the horizontal, even though they consist of easily-eroded strata. Evidently there has not been sufficient time for them to have been reduced much. Powerful tributaries, such as Barber's and Bungonia Creeks, have not been able to extend their gorges very far back into the tableland (Text-fig. 10), also on account of this lack of time, although it must be remembered that both have come against hard and fresh rocks which offer great resistance to erosion.

This gorge represents the latest work of the river, and the rate of cutting by such a powerful stream must have been rapid, especially in the weak meridional section. The whole time taken in this work must have been only a fraction of that which has elapsed since the formation of the 2,000 foot level before the period of Pliocene basalt flows. Small tributary streams such as Ruse's Creek have not yet had time in which to take advantage of the extra grade given them by the cutting of this trench. The lower valley of the stream in question is now becoming trenched, and it is only a matter of time before the gorge now being eroded will drain such swamps as those existing on tributary "1".

It might be argued that the formation of the small mature system quoted could easily have taken place whilst the canyon was being cut. That would mean that purely vertical erosion would have to be checked effectively in order to allow the formation of the existing grades (Text-fig. 10), and the lateral widening of the valleys after these profiles had, in their essentials, been attained. This hardly explains why the purely vertical cutting from the gorge or downstream side is taking place quite readily now, and it makes the dangerous assumption that the sandstones on which the lower parts of the mature profiles are found are particularly resistant to erosion—an assumption for which I can see no justification.

There is one place where one might expect to see vertical cutting checked, thus allowing considerable lateral widening of the valley. In part of its course Tallowa

Creek has cut down to particularly hard and massive porphyries (shown as intrusive on Text-fig. 2), which are overlain by rather weak fossiliferous sandstone of the Upper Marine Series. The process of downcutting has continued without any appreciable widening of the gully, despite the highly resistant nature of the porphyries, in which the stream is now entrenched to at least 150 feet, and possibly more further downstream.

We would conclude, then, that whilst upland valleys such as those of Ruse's Creek are still approaching more mature forms where they are not actually being trenched by headward erosion, still their formation as essentially mature features must have antedated the cutting of a gorge of even limited depth by the Shoalhaven. If we grant that this canyon only forty miles from the present coast is a recently-developed feature, we necessarily admit that it has only been made possible by comparatively recent major changes in the pre-existing order, and the only change competent to produce such results is one involving considerable uplift of the land surface after a period of stability. This uplift would be required to be of the order of 1,000 feet.

Land Forms.

Now that the greater part of the information is at our command, it becomes possible to survey the area broadly as a whole, and to collect the scattered conclusions which have already been reached. We shall begin with the upper surfaces and work downwards.

i. *Residuals and the Upper Tableland.*—The presence of sandstone residuals in horizontal rocks rising to 2,350 feet points to the existence of an old, high plain. The existence of similar and higher masses in the eastern part of the Wollondilly basin extends the area of such occurrences northward and, in fact, a considerable part of the Blue Mountain Plateau is involved.

Considering the Tallong-Bungonia area only, it is clear that not only is a previous higher level indicated, but that sedimentary strata of some kind must necessarily have existed over the present 2,000 foot level, giving it a surface of the order of 400 feet higher than at present. We might assume that the Shoalhaven Plain previously existed at an altitude higher by 400 feet than it does at the present day with respect to the upper surface of the more northerly sedimentary rocks, but such an assumption would only be justified in the light of some positive evidence, of which there is none at present. It would involve the postulating of differential uplift from north to south—an idea which seems to be contradicted by the uniformity of the 2,200 and 2,000 foot levels over wide areas in this region.

High residuals such as Vessey Trig. would appear to have existed several hundred feet above the maximum height of the newer sedimentary strata, in which case they would be strictly comparable with Mt. Walker, at Lithgow, which rises 600 feet above the highest sediments which rest on its northern side. Other similar places in the Cox Valley have already been cited. If the eroded Permian series about Ballanya Trig. Station were restored, it would be entirely covered, as residuals of the newer sandstones in the vicinity rise to the height of its crest. Its survival to the present day is due to the fact that it has been protected by the overlying strata, now removed.

ii. *Valleys of the Tableland.*—Defining the tableland proper as that surface now existing about 2,200 feet, we find that erosion has progressed in the tableland surface causing a widespread reduction of the order of 200 feet. That a considerable part of this reduction was accomplished before the period of basalt flows is shown both in this district, and northward in the Wollondilly area. Valleys eroded down to this level have been filled with basalt, some of the most notable examples being in the Moss Vale district. As the result of more recent erosion, a good deal of this basalt has been removed. The 2,000 foot level has been re-established and extended considerably, especially in the shales and sandstones to the north-east of the Tallong area. Proceeding southward over the Shoalhaven Plain, we do not see any reason for stating that this plain surface is essentially a post-basaltic feature: our most reliable indications are to the contrary, and indicate considerable age for this feature.

Unfortunately it has not yet proved possible to investigate the area lying to the east of the Shoalhaven River and towards the coast, but it appears to be an inclined plain rising from 2,000 feet near the river to 2,400 feet some 7 miles further south. The rise continues southward to the Sassafras and Currockbilly Ranges.

More recent erosion has resulted in the formation of shallow valleys below the general level of the Shoalhaven Plain and around the edge of the Caoura basalt flow. This would appear to antedate the cutting of the modern gorges.

iii. *Gravels and Stream Capture.*—The great "elbow" of the Shoalhaven River near Tallong, when considered in connection with the long northerly course of the river, has led to the suggestion of capture. Woolnough and Taylor postulated a former Shoalhaven-Wollondilly stream flowing northward past Tallong before the plateau was raised to its present elevation. According to this hypothesis the Shoalhaven below Tallong has been reversed by capture from the direction of the coast, and previous to this capture streams such as Kangaroo River had flowed westward to join the old main stream at Tallong (see Taylor, 1918, p. 151). The various writings of Taylor make it clear that he accepted this view as having been proved, but the field evidence originally adduced to support this view is not at all convincing.

If one accepts the view that a "normal" stream and its tributaries should have a "dendritic" or branching-tree pattern, such an elbow as that of the Shoalhaven at Tallong is abnormal, and requires a special explanation, such as one involving stream capture. Taylor accepted this view (1911, p. 8), and cited Kangaroo River, a tributary of the lower Shoalhaven, as indicating a former westward flow of the whole system before the formation of meridional streams such as the Wollondilly (*ibid.*, fig. 18c). He envisaged three main stages. First, streams such as the Shoalhaven and Mulwaree Creek flowing westward to the Abercrombie-Lachlan system. Second, these streams being diverted northward by a meridional monoclinal fold. Third, the combined westward and northward-flowing streams on the coastal side being diverted eastward by capture from the coast following the uplift of the modern tableland. I propose to consider this third stage specifically.

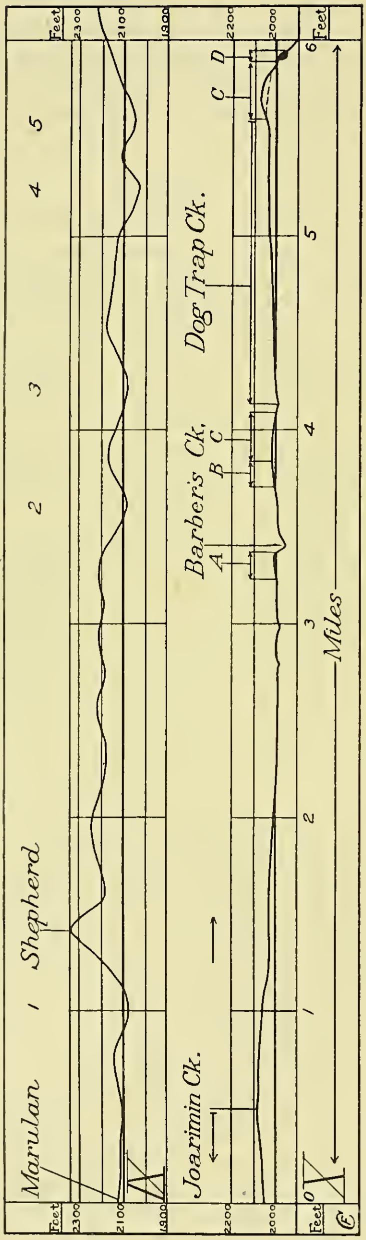
Field evidence in favour of an ancient stream channel across the highlands at Tallong depends on a continuous valley leading from above Digger's Creek to a gap in the Shoalhaven-Wollondilly divide near Shepherd Trig. Station, on the presence of stream gravels along the floor of this valley, and on the impossibility of the gravels having been derived locally.

In considering the gravels, whose general disposition is indicated in Text-figs. 8 and 9 and on Plate vi, it must be borne in mind that they lie immediately off the edge of the Permian conglomerates, which contain specimens of all the older rocks in the district, some of which have been brought from a distance. Masses of quartz-porphyry found at the head of Tallowa Creek, for instance, are six miles from the nearest stratigraphically higher porphyry at Marulan. A summary of the various occurrences of gravel and pebbles is instructive.

Locality or Occurrence.	Altitude at Base.	Thickness (in feet).	Rock Types.	Size of Pebbles.	Shape.
Permian Conglomerate	Maximum 2,150 ft.	Variable	Varieties of quartzites: cherts, jaspers, porphyries	Max. 3 ft.: 3 in. to 9 in. diameter	Angular to ellipsoidal
East of Ballanya	1,950 ft.	60	Brown quartzite and sandstone. Slates and cherts	2 ft. maximum diameter	Angular to ellipsoidal
Viaduct, Barber's Creek	2,000 ft.	15	Quartzites, jasper chert, quartz, indurated conglomerate	Maximum 3 ft. Generally 3 in. to 8 in.	Sub-angular or rounded
600 yards SE. of Viaduct	2,000 ft.	Surface	Silicified conglomerate and sands *in situ*	To 3ft.	Masses on ground surface
Eastern side Dog Trap Ck.	2,000 ft.	Surface	Brown quartzite	9 in.	Ellipsoidal
Dog Trap Ck.	1,960 ft.	In stream channel	Brown quartzite	To 18 in.	Sub-angular

The gravels east of Ballanya are apparently an outlier of the Upper Marine Series, and are described under the heading "Digger's Creek". Those at the viaduct are outwash on to the flood plain of Barber's Creek, which stream now flows at a lower level and does not reach this height. The occurrence of indurated conglomerate indicates that the gravels have been derived, in part, from the vicinity of the basalt flows. Some of this material is found *in situ* near the viaduct. The quartz pebbles to the east of Dog Trap Creek are just off the lower edge of the conglomerates (Text-fig. 2), whilst the stream channel contains boulders of granodiorite weathering *in situ*, and quartzite which may be derived either from the conglomerate or the older rocks upstream. This latter is only mentioned because it has been referred to as "redistributed stream gravel".

With regard to the stretch between the viaduct and the gap near Shepherd Trig., Woolnough and Taylor (p. 550) refer to "recent wash from the hills, overlying the old river gravels". Supposing that to be the case, the level of the gravel would be below 2,000 feet, and it is not the case towards the main road, where an undulating surface of normally weathering granite is exposed. On examining the gap to the west of Shepherd Trig. Station, it is found to exist at 2,080 feet, and outcrops of granite exist within 20 yards of the lowest part of this gap on either side, and at much the same level. Recent erosion on the southern side has disclosed 5 feet of sandy wash overlying clay, the latter containing rounded pebbles of weathering granite. Small fragments of quartz are found at intervals over the granite surface, and comprise some of the drift from the sedimentary rocks forming the hill of Shepherd Trig.



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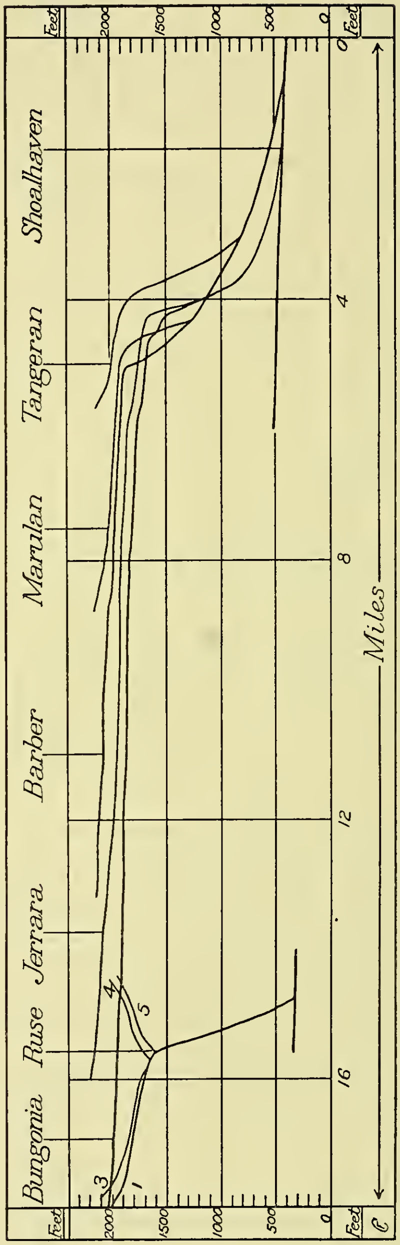

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Text-fig. 9.—IX shows a high-point line on the northern divide of Barber's Creek. Where necessary, short projections have been made on to the line shown on Plate vi to get the height of the actual divide. X is a profile from the east of Ballanya Trig. to Joarimin Creek. A = stream drift; B = contact quartzite; C = conglomerate drift; D = Upper Marine conglomerate above Digger's Creek. Vertical exaggeration = 5·9.
Text-fig. 10.—Profiles of the main streams. Note the predominance of the level about 2,000 feet, and the steep fall of the revived streams from the tableland. Ruse's Creek is shown separately for convenience. Vertical exaggeration = 8·8.

Now consider the two profiles IX and X (Text-fig. 9). The latter shows the ground over which the hypothetical ancient stream is supposed to have flowed. Its elevation would vary from 1,950 feet at the base of "D" to 2,040 as a minimum on the divide of Dog Trap Creek. A steady fall leads to the base of the gravels at the viaduct at 2,000 feet, whilst a sustained rise leads to the gap near Shepherd Trig. This curve does not represent the thalweg of a stream which flowed from "D" to Joarimin Creek as Woolnough and Taylor suggested, but it does represent a normal profile for streams flowing to such an ancient main stream as Barber's Creek.

Profile IX shows part of the northern divide of Barber's Creek. The deepest gaps are those at the head of Marsh's Creek, but Uringalla Creek as a whole has been very active in breaching its divide after having attained maturity. This curve demonstrates that the gap "1" near Shepherd Trig. is to be regarded as a normal feature of the landscape and, in view of the weathered granite exposed at this point and the proximity of the edge of the horizontal rocks, its presence is to be expected. There is no justification for assuming that a main stream flowed through this gap at one time when similar features exist at a lower level in the same divide.

A critical examination fails to reveal any field evidence in favour of a hypothesis of stream capture or of an ancient stream having flowed over this part of the land surface between the upper Shoalhaven and the Wollondilly. On the other hand, there is a considerable body of evidence which indicates that the present scheme of drainage has persisted since a time antedating the late Tertiary basalt flows.

The basalt-filled valley leading from Badgery's Lookout to Caoura, and existing below 1,900 feet, indicates a persistent eastern drainage over a long period, and discounts the idea that Kangaroo River flowed westward to Tallong at some time before the uplift of the present tableland. Corroborative evidence is found in the increasing amount of mature erosion as one goes eastward and in the appearance of incomplete cycles of erosion towards the coast.

The Shoalhaven Plain exists at about 2,000 feet, and would appear to be an ancient feature which has existed over a long period of time at a level below that of the sandstone tableland further north, and essentially below the divides between the Shoalhaven and Wollondilly systems. On either side of this divide similar topographic features are developed to levels below those of the divide itself. The level valley of the Wollondilly between Brayton (or Longreach) and Paddy's River at an elevation somewhat below 2,000 feet (Craft, 1928*b*), and the shallow valleys of the Bungonia Creek system incised in the 2,000 foot Shoalhaven Plain are cases in point. The latter especially is noteworthy, as it can probably be correlated with the small mature valleys of Ruse's Creek.

The ancient stream line as postulated by Woolnough and Taylor has left the wide lower valley of Barber's Creek out of the account entirely. W. R. Browne, in verbal communications to the writer, has stressed this, and has insisted that the intersection of the supposed with the actual stream line condemns the former, a conclusion with which I agree. It might be said that the upper Shoalhaven and the Wollondilly were once continuous by way of Barber's Creek, and that the lower part of the latter has been reversed by capture from the east. Apart from there being no field evidence to support this view, it is not necessary, and the objections cited above certainly apply to it equally with the original capture hypothesis.

In conclusion, we can state definitely that the present outline of the Shoalhaven River near Tallong represents its essential form since the development of the plain surface now at 2,200 feet; that the valley line between Digger's Creek and the gap near Shepherd Trig. Station does not represent the line of flow of a main stream, and that the idea of the Kangaroo River ever having flowed westward to or past Tallong must be dismissed. In considering the factors which may originally have determined the outline of the Shoalhaven River we enter the realms of more or less legitimate speculation.

iv. *Streams of the Area.*—The principal facts relating to the streams have already been disclosed, but they may be collected and summarized with advantage. As regards the actual profiles (Text-fig. 10), they are seen to be characteristic of revived streams. Barber's Creek flows at grade through its whole upper length. Jerrara and Bungonia Creeks flow at grade through the residual masses and over the plains before passing into narrow, level gorges without a great fall. They fall from these preliminary gorges in a series of cataracts to meet in a deep canyon. Their profiles show no disturbance such as one would find if their courses had been folded or faulted across (contrast Cox's River, Craft, 1928*a*).

The effect of the main stream is shown clearly by the steepness of the lower parts of these profiles. The Shoalhaven has reached grade rapidly, and by giving its tributaries the advantage of a great fall in their lower stages, it is enabling them to attack the tableland. The effective base-level of erosion is the level of the river where a tributary enters it. These streams contrast with those of the Cox, Grose and Colo systems of the Central Tablelands, most of whose tributaries have cut steep gorges right to their watersheds. The fact is emphasized that the last stage in the uplift of this more southern plateau was comparatively recent, so erosion of tributary gorges has not yet progressed very far. Erosion in the earlier stages of uplift had resulted mainly in the excavation of rather mature valleys, the greater part being done towards the coast.

Considering the actual shape of the streams, we are at once impressed by the great incised meander of the Shoalhaven below Barber's Creek, a feature which has been inherited from the original stream course at a higher level before the canyon stage began. Meanders on a much smaller scale are exhibited by Jerrara, Bungonia and parts of Barber's Creeks. In the first two cases the meanders persist right along the varying courses of the streams through residual ridges, over plains and, to a limited extent, in the gorges. In the residual country Jerrara Creek has inherited its meanders from the 2,100 foot terrace at least, as they are comparatively fixed in slight entrenchments at the present day. These circumstances agree with the remainder of the evidence, which points to a remote origin for these streams, even indicating that conditions to determine their origin were evolved about the time of the deposition of the Permian sediments. This only applies to the high western masses, which would appear to have supplied material for all of the newer sedimentary formations from the Permian onwards.

The lower part of the Shoalhaven flows some five miles to the south of the Hawkesbury Series, which appears to begin at Wingello, and continue eastward to the north of Tallowa Creek. A similar feature is shown by the Wollondilly River between Paddy's River and the Wanganderry bend, by the northward-flowing section of the Kowmung River, and by Cox's River from its junction with the Kowmung almost to its head. In each case the present edge of the Hawkesbury Series (Triassic) is of the order of five miles from the stream, and exists on one side only. It is suggested that these streams have a similar origin:

that the edges of the Hawkesbury Sandstone formation—itself probably of shallow-water origin—were loose and unconsolidated, and when the deposition of the Triassic strata was complete and the formation was first raised and exposed to the attack of the weather, the edges of the formation were readily eroded. Valleys so formed were occupied by the progenitors of the streams named, which flowed according to the local slopes to the sea. In time these streams established themselves and became permanent features of the landscape.

The basis of this idea has been current for a considerable time, and Taylor (1911, p. 14), suggests that the exposed soft "Permo-Carboniferous" strata favoured the development of the lower Shoalhaven, which is found about the present edge of the Upper Coal Measures. This suggestion is complementary to that repeated above which Taylor also recognized. It is as yet too early to attempt any explanation of the origin of the Shoalhaven above Barber's Creek, although its later development would doubtless have been favoured by the weak Ordovician structures which it has exposed. The supposed origin of the lower Shoalhaven is only to be taken as a supposition of reasonable possibility.

Soil and Water Supply.

An outline of the conditions of the soil and water supply of the area can be given both for purposes of physiography and economic geography. On the whole, the soil is of a sandy or gravelly nature. The conglomerate and sandstone tablelands near Tallong are rocky and hold little water. Valleys cut in them have a depth of soil up to 5 feet overlying pebble wash and this soil, in places, holds a good deal of water. These conditions give rise to swamps such as those found at the head of Barber's Creek and along its upper valley as far west as Tallong. The permanent water supply of Barber's Creek depends on these swamps, and is supplemented by soakage from the northern sides of the upland basalts. Drainage from the southern side of these latter areas passes into Tallowa Creek.

The basalts have a definite value in storing up water and releasing it gradually in dry times. The Caoura flow is divided into thin sheets which are split up by a series of close vertical joints. Water penetrates this readily, and is stored up in the cracks and interstices, with the result that small streams heading in the basalt are permanent, whilst those originating in nearby sandstone are liable to fail in dry weather. Water issuing from the base of the basalt is charged with minerals in solution; in dry weather its taste is unpleasant, but stock drink it readily enough.

Going westward and southward over the granite areas, we find a light sandy soil on the surface overlying clay subsoil. A good deal of water is stored in the surface layers, but it passes out readily during dry weather, so the normal flow of the streams in this part of the area is not so great as one might expect. They generally contain water, however, as sand beds in the rocky channels store a certain amount, and waterholes in the rocks or clay are fed by a slow percolation from the deep valley soils. The light surface favours rapid erosion after a dry spell during which the grass has been eaten off by stock or rabbits, but as this erosion is only very effective in country of such gentle slopes along the stream banks, the preservation of occasional trees on these provides an effective check, and helps to prevent waterholes which they shade from drying up altogether. Where all the trees have been cut away, the process of land destruction is becoming progressively more rapid, and can only be checked by planting suitable trees and grasses in the weathering banks.

The residual ridges have light, deep soil in their valleys and along their lower slopes, but as this is derived mainly from quartzites and porphyries, it is of a sandy nature, absorbing a great deal of water and giving it up readily either to streams or to the atmosphere. The ridges themselves are stony and arid, and their steep slopes make a high run-off inevitable. In places where they are being cleared and stocked the removal of the little soil is only a matter of time. As the valleys are largely eroded in shales, slates and occasional limestones, they are marked by much gentler slopes and, where deeply-weathered soil has accumulated, a fair amount of water is retained and gives a small permanent soakage to the streams. On the whole the residual country is dry, although its porous soil combined with the fact that much of the country is still forested tends to reduce the violence of floods, and to retard erosion.

Taking the remaining land—that on the Shoalhaven side of the granites—we find that the limestones and associated slates produce deep soil in level valleys. This holds water fairly well, and is useful for agriculture over limited areas along Ryan's Creek. The sink holes towards the Lookdown at Bungonia discharge water through underground tunnels into Bungonia Creek. East of the limestone belt there is a series of chert, jasper, slate and quartzite ridges. These are close to the edge of the Shoalhaven gorge and the steep slopes, combined with the strongly-jointed nature of the rocks, render them almost useless for the storage of groundwater. This applies to the slopes of all the gorges, which are singularly dry and waterless. In very steep places even scrub will hardly grow.

The effect of these conditions in the area as a whole is to give streams which, although they flood after heavy rain, still continue to run freely for a month after the ground has been saturated. In dry summers all of the streams are likely to dry up, with exception of the head swamps and lower courses of Barber's Creek; Tallowa Creek, which flows in a deep and sheltered gully, and the streams originating in the basalts. Barber's Creek only ceases to run in its middle portion during exceptionally dry summers, but Stony, Jerrara, Marulan, Bungonia and Tangeran Creeks hardly flow during the greater part of summer and autumn, although they all have permanent waterholes.

There is generally enough water for stock but, from the viewpoint of erosion, the drying of the watercourses and their surroundings in the hot season is unfortunate, as the ground cracks and is broken by stock, and the light soil is carried away easily by rain which succeeds the drought periods.

On the imperfect evidence available it would be unsafe to say that the clearing and settlement of the country is causing streams to become less permanent, but it is certainly accelerating erosion in the mature highlands.

Physiographic History and Summary.

Looking at this part of the Shoalhaven Valley we find that it consists of crumpled Ordovician rocks overlain by newer Silurian (?) and Devonian strata, the whole having been folded into a grand arch, of which the western limb is exposed in the Tallong-Bungonia area. The crest or axis is represented at the present time by the linear outcrop of Ordovician strata along the Shoalhaven River between Nerriga and Tallong. The crest and eastern limb of this arch were cut away by erosion to form a peneplain, upon which the Permian strata were eventually deposited. This surface was warped or folded down to the east and north-east, allowing a great accumulation of the newer sediments, but the western portion stood relatively high, and was flanked on the west by ridges of Devonian quartzites. Newer surfaces were built up by sedimentation within a few hundred feet of the crests of these ridges, and the older and newer strata have been subjected to erosion and denudation over long intervals of time. The history of the land forms may be thus summarized:

"Kanimbla Epoch" (Pre-Permian).—Folding of grand arch southwards. Formation of peneplain, with ridges to the west.

Permian.—Deposition follows subsidence, which was most pronounced to the east and north-east. Littoral beds in this area.

Triassic.—Deposition of Narrabeen, Hawkesbury and Wianamatta beds to the north-east.

Tertiary (provisionally).—Final development of modern stream systems, including lower Shoalhaven off the edge of the Hawkesbury Series.

Late Tertiary.—Earliest uplifts (?)—residuals of 2,350 foot level formed as the general surface was reduced to the modern 2,200 foot level. This peneplain existed near sea-level.

Uplift.—Erosion to a depth of 300 feet in plain, forming Shoalhaven Plain and associated levels. Erosion of Caoura Valley after further uplift.

Basalt flows (the "newer basalts").—These were considerably eroded, the lower plain was extended, and there was additional erosion towards the east, as at Ruse's Creek, and the formation of shallow valleys in the lower (Shoalhaven) plain.

Great uplift of the order of 1,000 feet in stages, resulting in considerable erosion and incomplete cycles of erosion towards the coast and a great removal of coal measure strata, but hardly affecting this area.

Erosion of modern gorges. Uplands in which streams have not been revived continue to progress slowly towards maturity.

In conclusion, it may be remarked that the views of Andrews (1910) and Sussmilch (1911-1922) regarding the development of the tableland surface are confirmed for this area, but the hypothesis of post-Tertiary stream capture advanced by Woolnough and Taylor is rejected.

Since this was written, a paper by G. F. Naylor on the drainage of the Marulan district has appeared. Working on the basis of Woolnough and Taylor's paper the writer accepts the hypothesis of stream capture, although he rightly rejects some of the earlier arguments in its favour. His arguments and conclusions, however, do not accord with a more detailed field examination, and many of them can scarcely be justified.

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EXPLANATION OF PLATES IV-VII.

Plate iv.

1. The Shoalhaven River at the junction of Digger's Creek. Note the terrace of detritus built up by the tributary.
2. View across the valley of Jerrara Creek, looking up Limestone Creek, a strike valley in limestone and slate. Vessey Trig. Station is to the right, and rises about 200 feet above the ridges on the left.
3. View down Jerrara Creek looking over Pearce's farm. The strike valley of the preceding view is in the foreground: a hard residual ridge is cut across by a consequent stream—Jerrara Creek—in the middle distance, and the Shoalhaven Plain is seen in the background. The most distant ridge is on the eastern side of the river.
4. The bed of Dog Trap Creek, about 600 yards above Barber's Creek. Note the fine wash resting on decomposing granodiorite. The smaller pebbles are of quartzite. This view is typical of the stream beds in the granite uplands.

Plate v.

Topographic Map of the Tallong District, eastern section. The Shoalhaven River is flowing between 300 and 400 feet above sea-level. Tertiary basalt flows are shown.

Plate vi.

Topographic Map of the Tallong District, western section. The main road and railway pass through Marulan. These maps are based on county and parish maps of the N.S.W. Lands Department, and topographic detail is by closed and corrected traverses, plotted originally on the scale of six inches to the mile. Vertical control by aneroid and Abney level.

Plate vii.

1. View from Warrima Trig. Station, showing Twin Trig. rising above the tableland at 2,200 feet with the head of Barber's Creek in the foreground.
2. The northern edge of the Caoura basalt flow, looking eastward. Basalt is in the foreground and to the right; the tableland at 2,200 feet is on the left and the scarp is one side of the pre-basalt valley steepened by modern erosion. Tallowa Creek flows in a gully to the left of the cleared basalt country.
3. The northern edge of Caoura basalt flow, looking eastward near Caoura station. Basalt banks are cleared in the foreground and on the right; the sandstone terrace, dissected by modern erosion, occupies the middle distance, whilst the tableland surface is seen in the distance.
4. The Shoalhaven River, looking upstream with the junction of Barber's Creek in the right background. View from above "McCallum's Selection".